PHYSICAL REVIEW C VOLUME 24, NUMBER 5 NOVEMBER 1981

Half-life of ^{180}Ta

Eric B. Norman
Nuclear Physics Laboratory, University of Washington, Seattle, Washington 98195

(Received 15 June 1981)

A search has been made for γ rays emitted following the electron-capture and/or β^- decay of ^{180}Ta. No excess of counts above background was observed in the vicinity of any of the expected γ-ray energies. From these results, lower limits on the partial half-lives of ^{180}Ta against electron-capture and β^- decay have been determined to be $\geq 5.6\times10^{13}$ and $\geq 5.6\times10^{13}$ yr, respectively.

[RADIOACTIVITY ^{180}Ta: measured I_γ; deduced lower limits for $T_{1/2}$, $\log ft$. Enriched source, Ge(Li) detectors.]

^{180}Ta is an interesting naturally occurring odd-odd nucleus. It is known to have a half-life of $>10^{13}$ yr and an abundance relative to that of ^{181}Ta of 1.2×10^{-4} (Ref. 1). In addition to this long-lived state, there is a $J^\pi=1^+$ level which β^- and electron capture decays with a half-life of 8.1 h.[1] Recently, it has been shown that this short-lived state is actually the ground state of the nucleus and that the long-lived level is an excited state approximately 80 keV above the ground state.[2-4] The spin and parity of the long-lived level had been thought to be 8^+. However, two recent experiments have shown that $J^\pi=9^-$ (Refs. 3 and 5). As a result of the renewed interest in this nucleus, a new experiment was performed in an attempt to determine the half-life of the long-lived ^{180}Ta.

The long-lived ^{180}Ta state is unstable with respect to both electron capture and β^- decay with decay energies of 935 and 799 keV, respectively.[4] Thus, this 9^- level would be expected to decay to the 6^+ state at 641 keV in ^{180}Hf and/or to the $(6)^+$ level in ^{180}W at 688 keV. It is also energetically possible for the 9^- ^{180}Ta level to electromagnetically decay to the 1^+ ^{180}Ta ground state or to the 2^+ first excited state. However, the lifetimes against these electromagnetic decays have been calculated and are found to be greater than 10^{27} yr.

The probable decay modes of the long-lived ^{180}Ta level are shown in Fig. 1 along with the known decay modes of the 1^+ ^{180}Ta ground state. The electron capture decay of the long-lived ^{180}Ta would produce a cascade of γ rays with energies of 332.3, 215.3, and 93.3 keV.[1] The β^- decay would produce a similar cascade with γ rays of energies 350.4, 234.3, and 103.6 keV.[1] In the present work, γ-rays singles and γ-γ coincidence experiments were performed to search for these γ rays.

A 30.5 mg sample of Ta_2O_5 enriched to 5.1% in ^{180} Ta was acquired on loan from Oak Ridge National Laboratory. The sample was supplied in a glass vial 1.4 cm in diameter and 4.6 cm long with

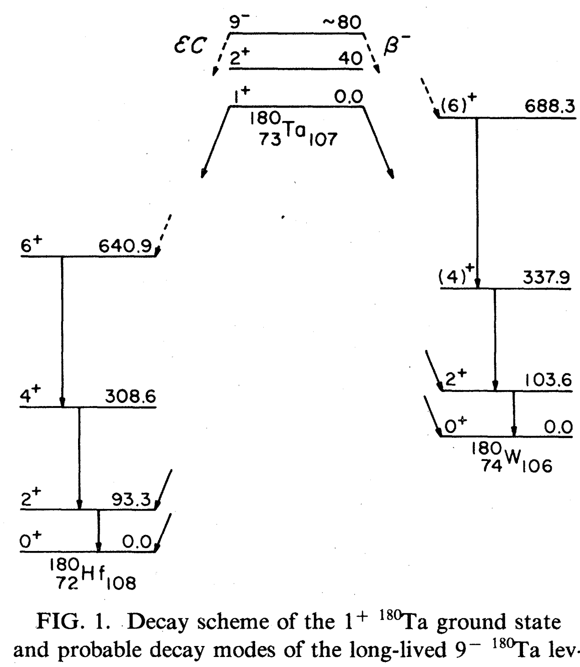

FIG. 1. Decay scheme of the 1^+ ^{180}Ta ground state and probable decay modes of the long-lived 9^- ^{180}Ta level.

wall thickness 0.18 cm. All counting was done with the sample in the vial. In the γ-ray singles experiment a 50-cm^3 coaxial Ge(Li) detector was used. The detector was located in the basement of Physics Hall at the University of Washington and was shielded with 2.5 cm of brass, 2.5 cm of borated plastic, and 10 cm of lead. Counting in the γ-ray singles mode was done for a total of 14 d. In the γ-γ coincidence experiment, a 79-cm^3 coaxial Ge(Li) detector was used together with the 50-cm^3 detector. γ-γ coincidence counting was done for a total of 11 d. γ-ray spectra were accumulated in either 1024 or 2048 channels using a multichannel analyzer. Energy calibrations and efficiency measurements were performed with standard γ-ray sources. For the 279.2 keV line of ^{203}Hg, the overall detector resolution was approximately 2.3 keV FWHM and the absolute photopeak detection efficiency in the experimental geometry was approximately 6.2%. Data was accumulated in 3-d periods and then recorded for subsequent analysis. Energy calibrations performed prior to each counting period allowed accurate determinations of the expected positions and widths of the ^{180}Ta decay lines.

The low energy portion of the γ-ray spectrum observed during 4.5 d of singles counting is shown in Fig. 2. Arrows indicate the expected positions of the ^{180}Ta decay γ rays. Except for a strong line at 93 keV, none of the expected ^{180}Ta decay γ rays are seen. The γ-γ coincidence spectra also showed no evidence of any of the expected ^{180}Ta decay γ rays.

To determine the origin of the 93 keV line and to gain further information on the background counting rate, a separate 30 mg sample of natural Ta_2O_5 was counted for 5 d in the singles mode. The shape of the spectrum observed with this sample was identical to that observed with the ^{180}Ta-enriched sample. The counting rates in the 93 keV peak from these two samples were also identical. The 93 keV peak thus is not produced by the decay of ^{180}Ta, but in fact is a product of the ^{238}U decay chain.[1] All of the other γ-ray peaks that are observed can also be attributed to the decays of U and Th decay-chain isotopes probably contained in the shielding material. The spectrum from the natural Ta_2O_5 sample was not used for the quantitative background measurements, but only to determine the general shape of the background and to help determine the origin of the observed lines.

Lower limits on the half-lives of ^{180}Ta against electron-capture and β^- decay were determined as follows. The centroid and width of each of the expected ^{180}Ta decay peaks was determined from the calibration measurements. A peak window was thus defined, and the spectrum from the ^{180}Ta-enriched sample was integrated over this window. In the same spectrum, background windows containing approximately as many channels as the peak window were then chosen above and below each peak window. A linear least squares fit was made to the observed background, and the results of this fit were used to determine the background rate in the vicinity of each of the expected ^{180}Ta decay lines. The reduced chi-squared values for all of these fits were close to 1.0, indicating that over the small energy range of interest for each peak the background does vary linearly with energy.

While the γ-γ coincidence spectra exhibited substantially lower backgrounds than did the singles spectra, the background rate was not as low as was

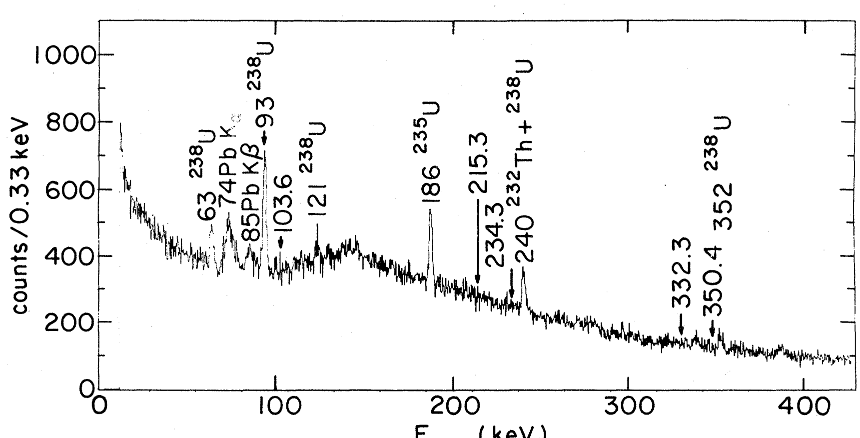

FIG. 2. Low energy portion of the γ-ray spectrum observed in 4.5 d of singles counting of the ^{180}Ta sample. Arrows indicate the expected positions of the ^{180}Ta decay γ rays.

TABLE I. Results of the present and previous experiments on the half-life of ^{180}Ta.

Author	Decay mode sought	$t_{1/2}$ (yr)
Eberhardt *et al.*, Ref. 6	β^-	$\geq 1\times 10^{12}$
Bauminger and Cohen, Ref. 7	β^-	$\geq (1.7\pm 0.6)\times 10^{13}$
	EC	$\geq (2.3\pm 0.7)\times 10^{13}$
Eberhardt *et al.*, Ref. 8	EC	$\geq 5\times 10^{9}$
Miller *et al.*, Ref. 9		$> 10^{11}$
Sakamoto, Ref. 10	EC	$\geq (1.5\pm 0.5)\times 10^{13}$
Ardisson, Ref. 11	EC	$> 2.1\times 10^{13}$
Present work	β^-	$\geq 5.6\times 10^{13}$
	EC	$\geq 5.6\times 10^{13}$

expected. Much of this true coincident background was apparently due to γ rays Compton scattering from one detector into the other. This effect combined with the lower detection efficiency in the coincidence mode made the limits obtained from these measurements less stringent than those obtained from the singles experiment.

The most stringent limit on the half-life against electron-capture decay was obtained from the search for the 215.3 keV line in the singles mode. The number of counts observed in the peak window over the total 14 d counting period was 10 813. The number of counts in this window due to background was determined to be 10 910. For the β^- decay mode, the most stringent limit was obtained from the search for the 234.3 keV line in the singles mode. The number of counts observed in this peak window was 9667, while the background was determined to be 9770. The net numbers of counts attributable to the 215.3 and 234.3 keV lines are thus -97 ± 148 and -103 ± 140, respectively. Taking the observed uncertainties as upper limits on the net numbers of 215.3 and 234.3 keV γ rays, the partial half-lives for electron-capture decay and β^- decay are found to be $\geq 5.6\times 10^{13}$ and $\geq 5.6\times 10^{13}$ yr, respectively. The corresponding log*ft* values for these third-forbidden nonunique decays are ≥ 20.8 and ≥ 20.1, respectively.

Table I shows a comparison of the present results with those of previous works. The results of the present experiment indicate that the apparent excess of counts near 215 keV observed in the experiment of Sakamoto[10] cannot be attributed to the decay of ^{180}Ta. The only other known third-forbidden nonunique β decay is that of ^{87}Rb to ^{87}Sr with a log*ft* value of 17.5 (Ref. 1). The substantially larger log*ft* values indicated for such decays of ^{180}Ta support the idea that these are highly *K*-forbidden transitions. The implication of this is that the actual half-life of ^{180}Ta may be significantly longer than the present experimental limits.

The author wishes to thank D. Bodansky and T. E. Chupp for careful readings of the manuscript. This work was supported in part by the U. S. Department of Energy.

[1]C. M. Lederer and V. S. Shirley, *Table of Isotopes,* 7th ed. (Wiley, New York, 1978).

[2]A. H. Wapstra and K. Bos, At. Data Nucl. Data Tables 20, 16 (1977).

[3]E. Warde, thesis, Université Louis Pasteur de Strasbourg, (1979); E. Warde *et al.,* J. Phys. Lett. 40, L-1 (1979).

[4]K. S. Sharma *et al.,* Phys Lett. 91B, 211 (1980).

[5]B. Burghardt, R. Harzer, H. J. Hoeffgen, and G. Meisel, Phys. Lett. 92B, 64 (1980).

[6]P. Eberhardt *et al.,* Z. Naturforsch. 10a, 796 (1955).

[7]E. R. Bauminger and S. G. Cohen, Phys. Rev. 110, 953 (1958).

[8]P. Eberhardt, P. Signer, W. Herr, and E. Merz, Z. Naturforsch. 13a, 1004 (1958).

[9]L. G. Miller, M. K. Brice, and M. S. Moore, Idaho Operations Office, Department of Energy, Report IDO-16505, 1958, p. 58.

[10]K. Sakamoto, Nucl. Phys. A103, 134 (1967).

[11]G. Ardisson, Radiochem. Radioanal. Lett. 29, 7 (1977).